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General Guard Wall Design Considerations for Tow Entry and Exit

by Howard Park

PURPOSE: The objective of this research is to provide design guidance that would allow field engineers to design approach guard walls that are safe and efficient to the users, while being cost-effective. The guidance available in EM 1110-2-1611 (Headquarters, U.S. Army Corps of Engineers 1980) and rule-of-thumb guidelines requires approach walls to be fairly long; therefore, the cost of implementing the approach walls can be substantial.

APPROACH WALLS: Guard and guide walls are a structural mechanism that towboats use to align with and enter the lock chamber. These walls are usually in both the upper and lower lock approaches. This Coastal and Hydraulics Engineering Technical Note focuses on guard walls located in the upper lock approach. A guard wall can be non-ported (without openings to pass flow), ported, and/or skirted (with openings to pass flow). A guard wall is the aligning mechanism that also protects the tow from flow drawn toward the dam in the upper lock approach or from flow discharged from the dam across the lower lock approach. Typically, a guard wall is located on the streamside of the lock. A guide wall, on the other hand, is basically just the opposite of a guard wall. A guide wall is strictly an alignment mechanism that does not protect the tow from river flow. A guide wall is typically located on the landside of the lock.

NECESSITY OF GUARD WALLS: Guard walls are a necessary and integral part of the lock and dam project. Imagine trying to steer a vessel that is 32 m (105 ft) wide and 343 m (1,125 ft) long that weighs 2.721554×10^7 kg (30,000 tons) into an opening that is 33.5 m (110 ft) wide (the lock) without some means of aligning the vessel with the opening to the lock chamber. Tows need some mechanism to come rest or near rest on, align with, and enter the lock chamber. This mechanism is the guard wall.

A tow moving in the direction of flow in the river must apply enough power to the tow to maintain steerage. In some instances a tow could be traveling between 8.05 and 16.1 km/hr (5 and 10 mph) downriver depending on river conditions and tow horsepower. However, as the tow approaches the lock, it must reduce power and forward speed to align with and enter the lock chamber (less than about 1.61 km/hr (1 mph)). As the tow reduces forward speed to avoid a substantial impact to the guard wall or other structural features at the lock and dam project, the tow is susceptible to the currents in the immediate vicinity. Typically, in the upper lock approach, the currents (crosscurrents) begin to move across the lock approach towards the dam. Where these crosscurrents go, the tow generally tries to follow.

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NAVIGATION CONDITIONS IN LOCK APPROACHES: Poor navigation conditions in the lock approaches produce traffic delays and safety concerns. Poor navigation conditions in upper lock approaches could be a result of too much outdraft or draw toward the wall. Upper approach guard walls produce outdraft and/or draw toward the wall. Significant crosscurrents in the upper lock approach upstream of the guard wall is generally termed outdraft and is caused from not allowing any or enough flow to pass through the guard wall. No crosscurrent in the upper lock approach upstream of the guard wall usually implies that all or most of the flow in the upper lock approach is passed through the guard wall and generally results in excessive draw toward the guard wall. The performance of a particular guard wall with respect to its navigability is based on these two factors and they are intertwined with each other.

Hydraulic design guidance, to assist the field engineer in designing guard walls, is incomplete. In the past and present, several rules-of-thumb guidance and from EM 1110-2-1611 (HQUSACE 1980) have been used to make a first cut design for upper and lower approach guard and guide walls. They are as follows:

- a. Provide a guard wall that is long enough to fully protect the design size tow for that particular lock.
- b. Typically port the upper riverside guard wall and provide the same port area in the guard wall as the intercepted flow area. (EM 1110-2-1611, paragraph 10-2 (HQUSACE 1980).
- c. Maintain the top of the ports in a ported guard wall at least 6.4 to 9.66 m (4 to 6 ft) below pool. EM 1110-2-1611, paragraph 10-2 (HQUSACE 1980).
- d. Provide an approach width wide enough for the design size tow to approach the guard wall 12 to 15 deg out of alignment.

UPPER APPROACH GUARD WALL DESIGN: In order to design an upper approach guard wall that performs well, one must balance the outdraft and the draw toward the wall, and minimize the adverse effects that each can cause with respect to the navigability. Outdraft is the flow that cannot be passed under the guard wall and thereby moves across the upper lock approach, around the end of the wall, and toward the dam. A significant amount of outdraft will generally move the head of the tow out of alignment with the guard wall and will require a significant amount of maneuvering for the tow to realign and enter the lock chamber. Increased maneuvering time results in increased transit times in which the lock becomes inefficient and cost the users money. Figures 1 and 2 are examples of significant outdraft and no draw towards the guard wall.

Draw toward the wall is the flow that moves into the upper lock approach and under the guard wall. The draw toward the wall can cause the tow to strike the wall at an excessive speed that could cause damage to the barges and/or guard wall. A significant draw towards the guard wall could also inhibit an upbound tow resting on the wall from departing the lock and proceeding upstream. Figure 3 shows an example of significant draw towards the guard wall and virtually no outdraft.

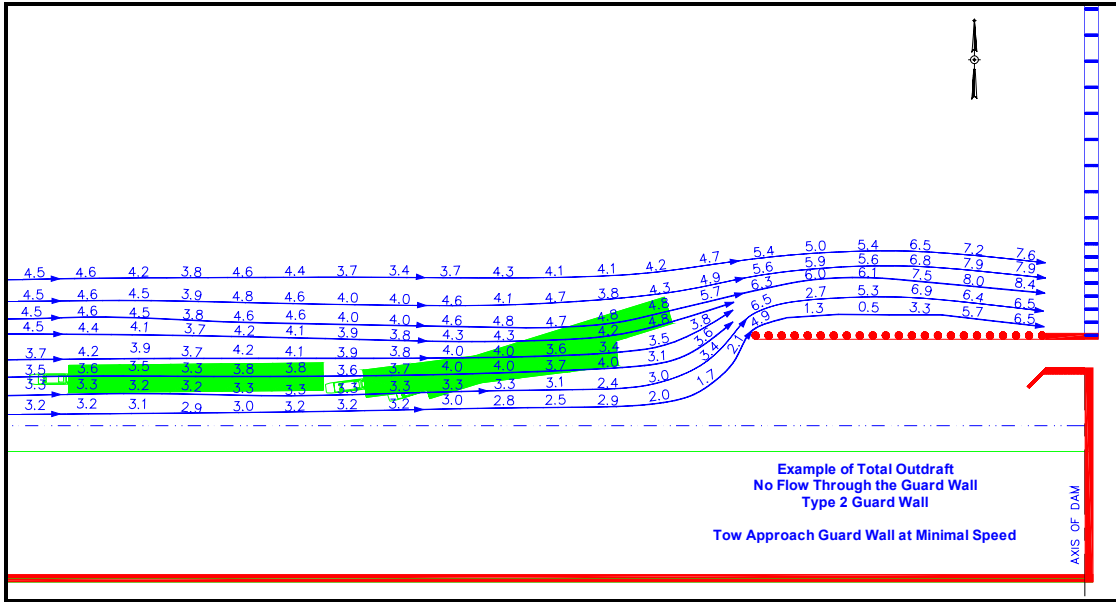


Figure 1. Example of total outdraft (no flow through guard wall). Tow is approaching guard wall at minimal speed. Observe how tow reacts to currents and is totally out of alignment with guard wall

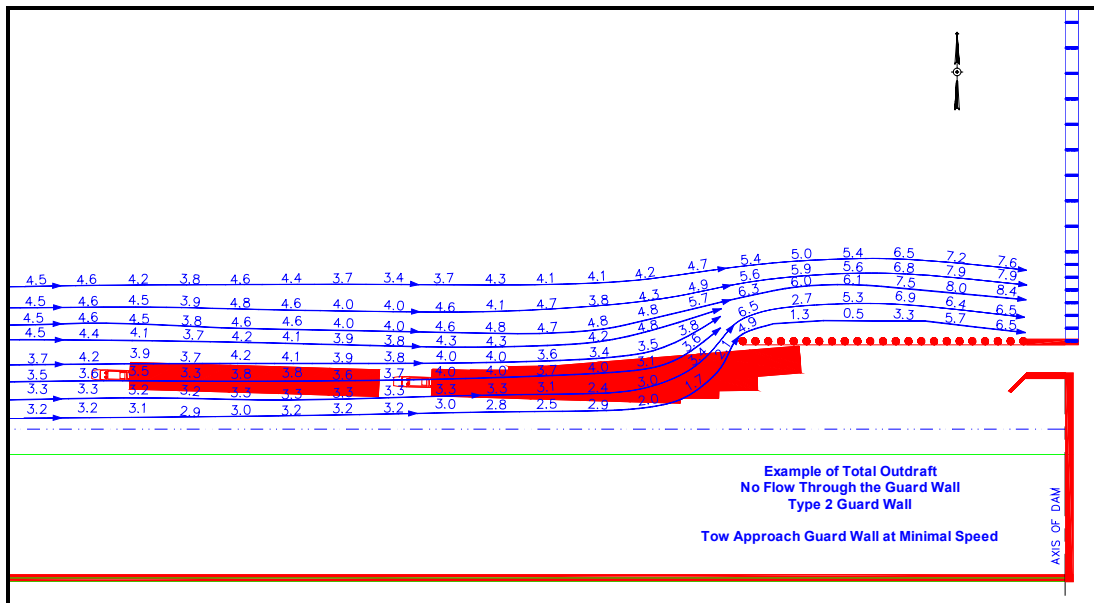


Figure 2. Example of total outdraft (no flow through guard wall). Tow is attempting to "punch through" outdraft. Observe that head of tow is near upstream end of guard wall

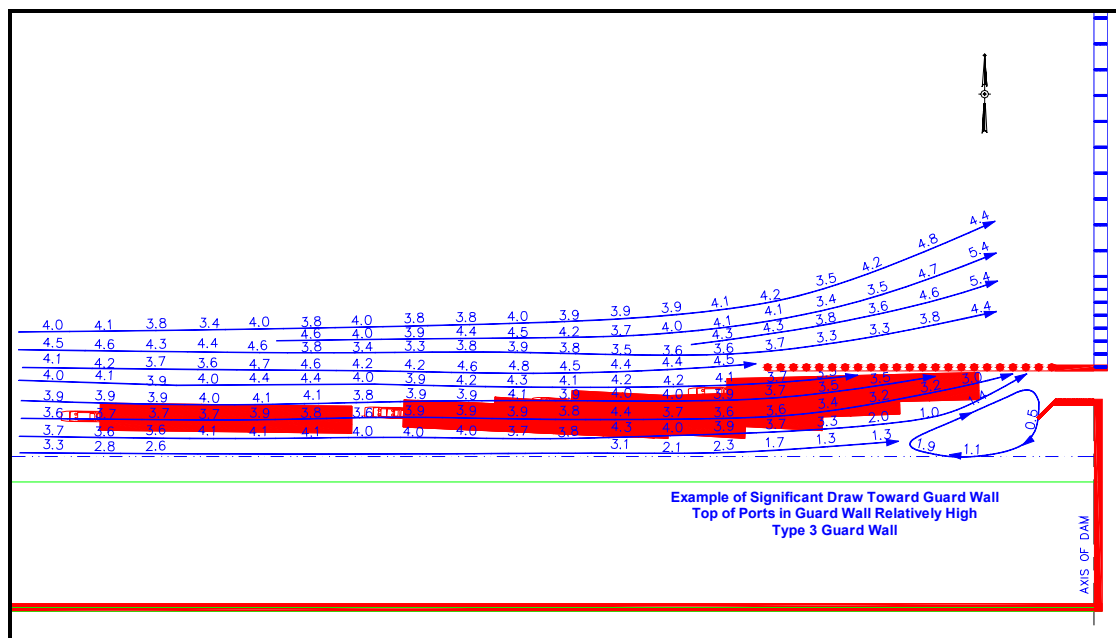


Figure 3. Example of significant draw toward the guard wall. Observe that there is very little outdraft and fairly high velocities moving toward guard wall

Either of these conditions result in unacceptable guard wall performance. Significant outdraft produces minimal draw toward the guard wall, whereas significant draw toward the guard wall produces minimal outdraft.

LOCK APPROACH CONFIGURATIONS ADDRESSED: A physical model study was conducted to address three basic guard wall configurations. They are multicell, floating, and long-span guard walls. Conceptually, a multicell guard wall consist of a series of circular driven sheet pile cell spaced 15.24 m (50 ft) on center with a concrete cap / rubbing surface that connects them together as a unit. The port openings in the guard wall that regulate flow are formed by attaching sheet metal draft curtain between the cells.

A long-span guard wall consists of circular driven sheet pile cells spaced 45.7 m (150 ft) on center and are connected with a precast concrete beam that also serves as a rubbing surface. The port openings in the long-span guard wall are generally in the 30.48-38.1-m (100-125-ft) wide range. The flow is regulated through the ports with draft curtains connected to the precast concrete beam.

A floating guard wall is a large hollow concrete pontoon. They can be constructed in modular sections. Dimensions of the pontoon vary, but are usually about 4.572-6.096 m (15-20 ft) high by 9.144-12.192 m (30-40 ft) wide and draft about 3.048 m (10 ft). Flow is regulated under the floating guard wall by draft curtains attached to the bottom of the pontoon.

The physical model was configured to represent a single lock chamber with clear chamber dimensions of 33.5 m (110 ft) wide by 387 m (1,270 ft) long having the capacity to handle a 15-barge flotilla 32 m × 297 m (105 ft × 975 ft) and pusher 45.7 m (150 ft) long having a total length of 343 m (1,125 ft). A remote control towboat was operated and used to evaluate each guard wall design.

Based on numerous U.S. Army Corps of Engineers initiatives to extend existing locks from 183 m (600 ft) to 366 m (1,200 ft) or to add new 366-m (1,200-ft) locks, the initial series of tests were conducted with multicell, floating, and long-span guard walls having nominal lengths of 366 m (1,200 ft). An initial approach width of 76.2 m (250 ft) (approximately 2.5 beam widths) was determined based on the rule-of-thumb guidelines previously mentioned. Sketches of these guard walls can be seen in Figures 4-6, respectively.

A second series of tests were also conducted with multicell, floating, and long-span guard walls. The approach width for the guard walls was increased to 152.4 m (500 ft) (approximately 5 beam widths). Model tests were performed to determine what adjustments to the guard wall length and ports heights would be required to provide acceptable navigation conditions with the wider approach width.

GUARD WALL DESCRIPTIONS:

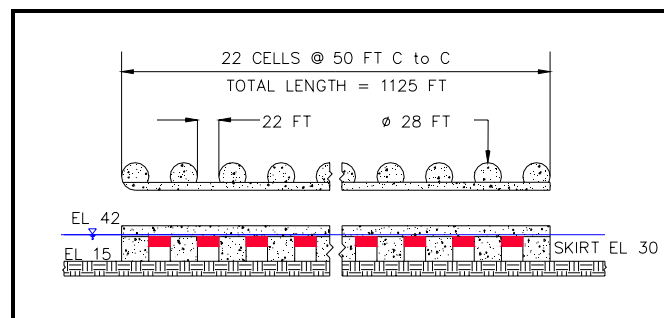


Figure 4. Multicell ported guard wall with skirts

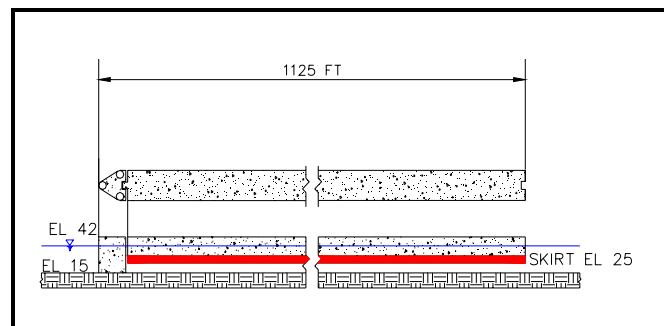


Figure 5. Floating guard wall with skirts

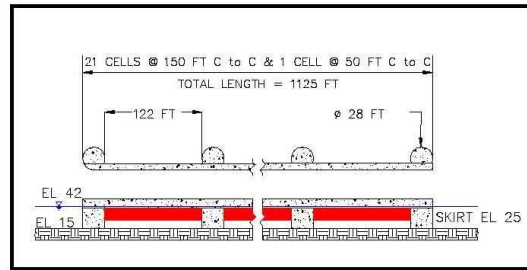


Figure 6. Long span sorted guard wall with skirts

Port heights, intercepted cross-sectional area, and wall length were varied to evaluate wall performance with respect to navigability.

MODELING METHODS: To evaluate the performance of a particular guard wall, many parameters are needed in the testing matrix. A numerical model was added to the study approach to streamline testing by evaluating and screening a multitude of guard wall configurations. The screened designs could be used as a starting point for refinement in the physical model. A 2-D depth-averaged hydrodynamic code, HIVEL2D (**Note:** The 2D module of ADH has replaced HIVEL2D), was modified and used to screen different guard wall designs (Stockstill 2001).

The initial guard wall tests consisted of a single multicell guard wall with an approach width of 76.2 m (250 ft). The model was operated with an approach velocity of about 1.2 m/sec (4 fps) and a flow depth of 8.2 m (27 ft) (three times draft of a loaded barge). Four different guard wall types having different port opening heights were installed in the model. The Type 4 guard wall provided the best navigation conditions as far as balancing the outdraft and draw toward the guard wall. The Type 4 guard wall was a multicell guard wall with draft curtains set to provide a uniform port opening height of 4.6 m (15 ft).

After validating the numerical model to the Type 4 guard wall configuration (Stockstill 2001), the numerical model was then used as a screening tool for other guard wall configurations to be further evaluated and refined in the physical model. Relative outdraft and draw toward the wall forces (Stockstill 2001) were generated for numerous guard wall types, and the guard wall configuration that “balanced” the two the best was generally chosen and evaluated in the physical model.

GENERALIZED RESULTS: Laboratory tests and Stockstill (2001) suggest that optimizing the ratio of the sum of the total port area in the guard wall to the sum of intercepted cross-sectional area would balance the outdraft and draw toward the wall. The following ratios ($\sum A_{\text{ports}} / \sum A_{\text{xs}}$) were determined in the physical model for a single multicell, floating, and long-span guard walls with nominal lengths of 366 m (1,200 ft) that provided acceptable navigation conditions.

APPROACH WIDTH, 76.2-m (250-ft) (\approx 2.5 flotilla beam widths):

Multicell : $\sum A_{\text{ports}} / \sum A_{\text{XS}} = 0.9$

Long span : $\sum A_{\text{ports}} / \sum A_{\text{XS}} = 1.4$

Floating : $\sum A_{\text{ports}} / \sum A_{\text{XS}} = 1.9$

A 30 percent or so reduction in port heights in the downstream one-fourth to one-third of the guard wall length, typically should improve the guard wall performance

With the long span and floating guard walls, the ratio of the $\sum A_{\text{ports}} / \sum A_{\text{XS}}$ increased compared to that observed with the multicell guard wall. With the long span and floating guard walls, outdraft is reduced due to the fact that more of the flow is going under the guard wall. The draw toward the guard wall is not excessive with the long span or floating guard wall due to the angle the approach flow makes towards the guard wall. The circular cells, such as the case of the multicell and long-span guard walls, tend to act as flow vanes and thereby produce more of a perpendicular approach flow angle towards the guard wall.

APPROACH WIDTH, 152.4-m (500-ft) (\approx 5.0 flotilla beam widths): Tests were performed with the same basic guard walls that were tested for the narrow approach width. With the wider approach width and the same basic guard walls, the intercepted cross-sectional area, A_{XS} , increased almost twofold. Thus, the ratios of the $\sum A_{\text{ports}} / \sum A_{\text{XS}}$ decreased to almost half those observed with the narrow approach width.

These ratios indicated that outdraft should be observed during model testing. The model confirmed that significant outdraft occurred with no adjustments to the guard wall port heights and/or length.

In order to maintain the balance of outdraft versus draw toward the wall, the guard wall lengths would need to increase with increased approach width.

Wider approach widths do provide more margin for pilot error and a sense of security. However, significant maneuvering may be required for tows to align with and enter the lock chamber due to significant outdraft. This increased maneuvering results in increased transit times from the arrival point to departure point of the locks.

Therefore, wider approach widths and nominal 366-m (1,200 ft) guard walls do not necessarily assure improved navigability, but do allow more room for error.

COMPARISON OF PREVIOUS MODEL STUDIES / PROTOTYPE VS. RESEARCH RESULTS: Particular current and previous site-specific model studies were compared with the results of the research done thus far. The following tabulation provides information on some of the projects.

Project	Model Or Prototype	Outdraft, Draw, or Balanced	Guard Wall Type	$\Sigma A_{\text{ports}} / \Sigma A_{\text{XS}}$ Site Specific or Prototype	$\Sigma A_{\text{ports}} / \Sigma A_{\text{XS}}$ Research
Olmsted L&D Ohio River	ongoing model	balanced	floating	2.0	1.9
London L&D Kanawha River	ongoing model	balanced	long span	1.6	1.4
L&D No. 4 Mon. River	ongoing model	balanced	long span	1.0	1.4
Greenup L&D Ohio River	on going model and prototype	some outdraft	multicell	0.8	0.9
J.T. Meyers L&D Ohio River	ongoing model and prototype	outdraft	multicell	0.2	0.9

The Olmsted, London, and L&D 4 model studies performed prior to this research generally agree with the research findings to date. The Greenup and JT Meyers projects are model studies that have just begun. The comments made by users, indicate that both of these projects have either some or significant outdraft difficulties. A comparison of the ratio of total port area to intercepted cross-sectional area at these two projects suggest that the Greenup project may have a slight problem with outdraft and that the J. T. Meyers project has a fairly significant problem with outdraft.

SUMMARY:

- Research was directed toward providing approach guard wall design guidance.
- Ratios of $\Sigma A_{\text{ports}} / \Sigma A_{\text{XS}}$ were developed to serve as an initial design tool for guard wall design.
- The ratios developed compare well with previous and ongoing model studies.
- Wider approach widths do not necessarily assure improved navigability.
- Wider approach widths imply the need for additional guard wall length for improved navigability.

ADDITIONAL INFORMATION: Questions about this technical note can be addressed to Howard E. Park (601-634-4011; e-mail: Howard.E.Park@erdc.usace.army.mil). This technical note should be cited as follows:

Park, H. E. (2002). "General guard wall design considerations for tow entry and exit," ERDC/CHL CHETN-IX-8, U.S. Army Engineer Research and Development Center, Vicksburg, MS. <http://chl.wes.army.mil/library/publications/chetn/>

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